Tipping Points, Abrupt Opinion Changes, and Punctuated Policy Change

by
William A. Brock[i]
Department of Economics
University of Wisconsin, Madison
December 17, 2004
Revised May 6, 2004

1. Introduction

Why is the political system sometimes so sluggish in dealing with environmental problems and at other times capable of very rapid responses? To put it more generally, why does the political system sometimes seem so slow and backwards looking when the capitalist system seems so pro-active, nimble, and forwards looking? No one doubts the tremendous benefits bestowed upon humankind by the creative dynamism of capitalism but the rapid change and continual introduction of new technologies rapidly increases the number and magnitude of negative externality problems that governments must control in order to optimize benefits net of external costs.

Governments seem to be losing the race to create effective institutions to do this job. It is easy to list current symbols of this mismatch: (i) SUV's continue to multiply, putting small car owners in increasing danger of colliding with one of these behemoths; (ii) McMansions continue to gobble up the landscape while the tax system still encourages this wasteful consumption that spoils the views of others; (iii) use of lawn chemicals continues unabated though lakes are eutrophied and water wells are poisoned; (iv) pollution from industrial agriculture and factory farms continues to increase while evidence of the increasing "off the books" costs of our "cheap food" policy is there for anyone to see. One can go on with a depressing litany of similar ailments where the "cure" is clear but action is lacking.

It almost seems as if, since environmental goods are "free" until government gets organized to regulate and impose costs for using them, that too much of technical "progress" evolves to economize on these "free" inputs. Clearly, if there were no governmental (or other "social" controls such as "social stigma" and ethical norms) innovation would continue to economize on priced inputs and use non-priced inputs to the point where society itself might ultimately collapse under the weight of its own wastes. I call this process "Flat of the Curve Induced Innovation."

Indeed, Nordhaus (1992) lists this inability of the political system to react as a potential limiting factor to human progress that might be more serious than the usual limiting factors of exhaustible and renewable resources that capture the attention of ecologists and other natural scientists in debates about the "limits to growth." For example, in discussing potential limits to growth, he states,

> *"One possibility is that the scale of human activity could overwhelm the capacity of the globe to tolerate industrial wastes, this, in turn, could drive the cost of reducing or recycling wastes to astronomical levels. This is the "scale limit." A second possibility is the "political limit." While reducing harmful side effects is in principle possible at modest cost, human societies might lack the political will or skill to take measures to internalize the externalities."*

Thus, the fate of society may ultimately depend on whether the human race wins this "human race."

Negative externalities from consumption patterns may even be more important than negative externalities from production patterns. The process is the same Flat of the Curve phenomenon in which people use non-priced inputs to satisfy their desires, driving the increment in satisfaction towards zero. A major role for social norms, social stigmatization and ethics is to check this process if government is not doing its job but there is evidence that these social mechanisms are not adequate. Brock and Taylor (2003b) report data on several major pollutants, which show that industry's share has dropped while consumption's share has risen.

A current metaphor for failure of social mechanisms is the continued growth of behemoth SUV's, which offload uncompensated risks onto other drivers while SUV owners seem to act as if they have a right to drive the things without paying compensation for the negative externalities they impose on the rest of the motoring public. Despite attempts to instill stigma, norms, and ethics via such campaigns as "What Would Jesus Drive?" the social mechanism of internalizing these externalities does not appear to be working.

Notice that the political system sometimes does act if the pressure is strong. Witness the nimbleness of Congress to act to protect the "Do Not Call List" as the courts kept throwing up roadblocks under the guise of rather generous interpretations of the Founding Fathers' intent to protect free speech. Congress knew that over 50 million people signed up for this popular list. When the median voter moves to a transparent position with enough intensity, the political system can (and will) act quickly. But the mystery remains: Telemarketers have been annoying the public for a long time--why the sudden action by government at this particular moment? The problem was obvious to all for a long time. Then, suddenly, a rare bipartisan consensus of both houses of Congress as well as the Executive rapidly "tipped" against an incredibly powerful special interest group (the telemarketing lobby). Why did this abrupt change occur after a long period of inaction in the face of long-standing public frustration? We try to shed light on such abrupt changes in government policy responses to long- festering problems with the models developed in this paper.

Natural and social scientists have worked hard to understand dynamical processes that produce punctuated equilibrium behavior. There are many kinds of models that do so: "sand-pile" models, "tipping point" models, "small world" models and other graph-theoretic models, "complex adaptive systems" models and models that produce punctuated dynamics via a hierarchy of time scales.[ii]

Unfortunately, despite the emergence of terms like "power laws", "scaling laws", "tipping points,", "complex systems," into the popular culture and despite the enormous publicity given to work in the complex systems area, there is a very difficult "identification" issue that must be faced by social scientists: Many dynamical processes that have little to do with complex systems processes produce identical empirical patterns. This problem is closely related to the well known "identification problem" in econometrics: How does one use data to distinguish among observationally equivalent structures? Such an identification problem turns up in the attempt to use data to separate "true" social dynamics that produce punctuated equilibrium behavior from "spurious" social dynamics created by exogenous dynamics of unobserved variables.[iii] This identification issue is especially important in deciding whether the sluggish political system acts suddenly because of "endogenous" emergence of pressure which "tips" it or whether it acts suddenly because an exogenous change acts on it, a change that may have little to do with the punctuated equilibrium dynamics of policy change discussed by Gunderson and Holling (2002)).

In this paper we present some simple models of the dynamics of problem recognition, the emergence of pressure from the public to do something about it and the final tipping of the system into political action. While we will not be able to resolve the tough empirical identification issues mentioned above, we will occasionally warn the reader about them. We concentrate in this paper on modeling the self-emergence of pressure on the political system. Then we apply these models to some of the policy problems as well as to some of the ideas that are considered elsewhere in this volume.

2. Minimal Models of Social Choice Dynamics: The "Mean Field" Case

This exposition uses ideas from discrete choice theory in economics and simple models of phase transition from statistical physics to model why social systems may get stuck in "social traps". The goal is not only to understand why a social system cannot move to a more efficient state but also to help find ways to break out of social traps.[iv] The basic idea of discrete choice theory is that the preferences (Anderson, de Palma, and Thisse (1992)), of agent *i* are stochastic, and are composed of a deterministic part and a random part. Scheffer et al. (2000), (2003), hereafter, S(2000), S(2003), use discrete choice theory and build on the work of Brock and Durlauf (1999) in modeling abrupt paradigm shifts in science and Brock and Durlauf's (2001a,b), hereafter, "BD(2001)", general treatment of interactions-based models to model the emergence of new problems, followed by lagged recognition, followed by eventual action mobilization of pressure on the political system, followed by possible action by the political system.

This work modeled not only tipping points and such other social interaction phenomena as peer group effects and social capital but also emphasized the empirical difficulties of using data to separate such phenomena from correlated observables and selection effects. "Selection effects" refer to the general tendency for social groups to self-select because they share common preferences, experiences or constraints, many of which are impossible for an empirical scientist to observe. It is very difficult to use observational field data to distinguish the effects of commonly shared unobservables from endogenous social dynamics, which are associated with the currently popular phenomenon of social capital.[v] In order to infer the correct policy action it is important to separate endogenous social interactions from exogenous social interactions If the social interactions are endogenous, there is scope for policy action to catalyze "good" social interactions with some sort of incentives and to discourage "bad" social interactions, i.e. attempts to discourage formation of "bad" social capital in certain socially pathological groups. These efforts of government would be wasted if the social interactions turned out to be spurious.

This chapter discusses the potential for abrupt change, bifurcations, hysteresis, and other dynamic phenomena, as does the work of S(2000), and S(2003). "Bifurcation" refers to a change in a stable state of a dynamical system at a faster time scale when a parameter on slower moving time scale goes through a critical value that causes the stable state on the fast time scale to become unstable. "Hysteresis" refers to a behavior of a dynamical system caused by a parameter slowly moving "up", such that the dynamical system shifts to an alternative stable state on a faster time scale when the parameter moves "up" beyond a certain critical value, but to "recover" the old stable state that same slow moving parameter has to be brought "down" to a level quite far below the original value that triggered the move in the first place. This is a phenomenon of partial irreversibility that is important in the benefit cost analysis of ecological systems, e.g. lake systems where oligotrophy and eutrophy are alternative stable states (Gunderson and Holling (2002)).

Now consider a community of social agents, call them i=1,2,...,N, facing two policy options, call them -1,+1. Let the status quo be -1 and let the difference in utility for agent i between the two options be denoted by

(2.1) $H_i(t) = h_i(t) + n_i(t)$,

where n is a random variable and h is deterministic; i.e., just some number. Notice that we are allowing both h and n to depend upon the agent and time. This heterogeneity across agents and time will be used later. Under standard assumptions used in discrete choice theory (BD(2001)), the probability that agent i chooses +1 in period t is given by,

(2.2a) $P\{\omega_{i,t} = +1\} = P\{\text{i chooses} + 1\} = \dfrac{\exp(bh_{i,t})}{\exp(bh_{i,t}) + 1}$, where the parameter "$b$" scales linearly as the inverse of the standard deviation of n (Anderson, de Palma, and Thisse (1992), hereafter ADT(1992)). That is, "b" increases to infinity as the standard deviation of n goes to zero. We call "b" the "intensity of choice". Notice that the function

$$(2.2b)\quad f(x,b) = \frac{\exp(bx)}{\exp(bx)+1},$$

is increasing in x, is 1/2 at $x=0$ for all b, is 1/2 for $b=0$ independently of x, and has a sharp threshold at $x=0$ for huge positive values of b. To put it another way as b increases from zero to infinity the function $f(x,b)$ goes from a horizontal line at 1/2 to a function that is zero for $x<0$, 1/2 at $x=0$, one for $x>0$. That is, as the intensity of choice increases from zero to infinity the probability that agent i chooses +1 when $h_i(t)>0$, (+1 is the "best") goes to unity as b goes to infinity. Equations (2a,2b) give a convenient way to model increasing precision in choice as the random variability of an agent's preferences decreases. We shall see that the interaction between peer effects and precision of choice creates interesting social dynamics.

Let us illustrate how this type of model works by using the example of scientific paradigms (Brock and Durlauf (1999)). In order to minimize notation, let v(+1), v(-1) denote the systematic parts (i.e. the deterministic parts) of the utilities or values imputed by each scientist to theory +1 and theory -1 respectively. Assume these systematic values are the same for all scientists. Represent the peer effect of the scientific community by the following formulation,

$$(2.3)\quad du \equiv u(+1) - u(-1) = v(+1) - C(+1-a(t))^2 - \left[v(-1) - C(-1-a(t))^2\right]$$

$$= v(+1) - v(-1) + 4Ca(t) \equiv h_{i,t} + 4Ca(t),$$

where

$$(2.4)\quad a(t) \equiv \frac{1}{N}\sum_{i=1}^{N}\omega_{i,t},$$

and $\omega_{i,t} \in \{+1,-1\}$ is the actual choice of agent i at date t and $a(t)$ is the average choice of the group at time t.

Now *"C"* represents the cost to a scientist who deviates from the paradigm currently held by most of the scientific community. This cost is well known to any scientist who has tried to publish a paper in a journal whose editors follow the entrenched paradigm. Similarly Courtney Brown (1995) discussed the role of such peer effects in creating non-linearities in changes of voters' feelings towards candidates.

Another important related example arises in modeling party discipline and party loyalty in legislative voting. The cost "*C*" represents the cost to a legislator from deviating from the party line (which is represented by the average "*a*" here) on a particular piece of legislation. This cost could be imposed by the party leadership. The parameter "*b*" captures the intensity of the representative's position on the issue, for (+1) or against, (-1) a particular piece of legislation whereas the deterministic part, $h_{i,t}$ captures the systematic part of the representative's preferences. For example "*b*" could be quite large for a prominent issue about which the constituency cares greatly but "*b*" could be quite small for issues that are of little moment to voters or on which the constituency is evenly divided. Here, peer effects induced by party discipline dynamically interacting with issue dispersion within legislative districts could cause a legislature to exhibit punctuated behavior much like a scientific paradigm shift.

Let us reiterate the meaning of (2.3) and (2.4) in the context of scientific theory choice. The "systematic" difference in "utility" to scientist *i* at date *t* between theory +1 and theory -1 is the difference in *v*'s adjusted for a peer effect where the scientist is "punished" for deviating from the average choice (2.4) of the scientific community. For example if most of the scientists are choosing theory -1, the peer effect punishes scientist *i* for choosing theory +1. In this case scientist *i* will have to prefer theory +1 quite strongly to pay the price of breaking away from the scientific consensus. This peer effect creates a consensus that "tightens" as the intensity of choice *b* increases towards perfect precision of choice, i.e., as *b* increases towards infinity. High values of *b* create "social traps" and historical "path dependence" even when the peer effect *C* is small and even when theory -1 is inferior to theory +1. A decrease in value of *b* can "open" the basin of attraction of a bad outcome and allow the dynamical system to "escape" such a bad basin of attraction. Here, the basin of attraction of a stable state of a dynamical system is the set of all initial conditions that carries the dynamical system's action to that stable state. We shall develop these ideas below.

There are several leading ways to formulate the dynamics of choice from this point on. A first way is to assume that each agent i forms expectations about the average choice $a(t)$, call it, $a(i,t)$ and chooses action according to

$$(2.5)\quad P\{\text{i choose}+1\}=\frac{\exp\left[b\left(h_{i,t}+4Ca(i,t)\right)\right]}{\exp\left[b\left(h_{i,t}+4Ca(i,t)\right)\right]+1}$$

As before, the individual's likely choice will depend on his or her assessment of total value, which includes a peer effect estimated on the basis of the individual's expectations regarding the consensus position. This raises the issue of how to model the dynamics of expectation formation of $a(i,t)$ for each agent. Some simple cases are

(2.6) $a_i(t)=a(t-1)+\phi a_i(t-1)$ (adaptive expectations), $0<\phi<1$)

(2.7) $a_i(t)=a(t)$ (perfect foresight).

Let us illustrate by assuming $h_i(t)=h$ for all agents i and for all time periods t. Assume expectations of all agents about the average behavior of the community are given by (2.6) with

(2.8) $a_i(t)=a(t-1)$.

That is, every agent i expects the community-wide average chosen next period to be the same as it was last period. Then, except for random variation resulting from very small communities,

$$(2.9)\quad a(t)=P\{\text{i choose}+1\}-P\{\text{i choose}-1\}=\frac{\{\exp[bh+b4Ca(t-1)]-1\}}{Z(t)},$$

$$(2.10)\quad Z(t)=\{\exp[bh+b4Ca(t-1)]+1\}.$$

Call the difference

(2.11) $a(t) = P\{\text{i choose} + 1\} - P\{\text{i choose} - 1\}$,

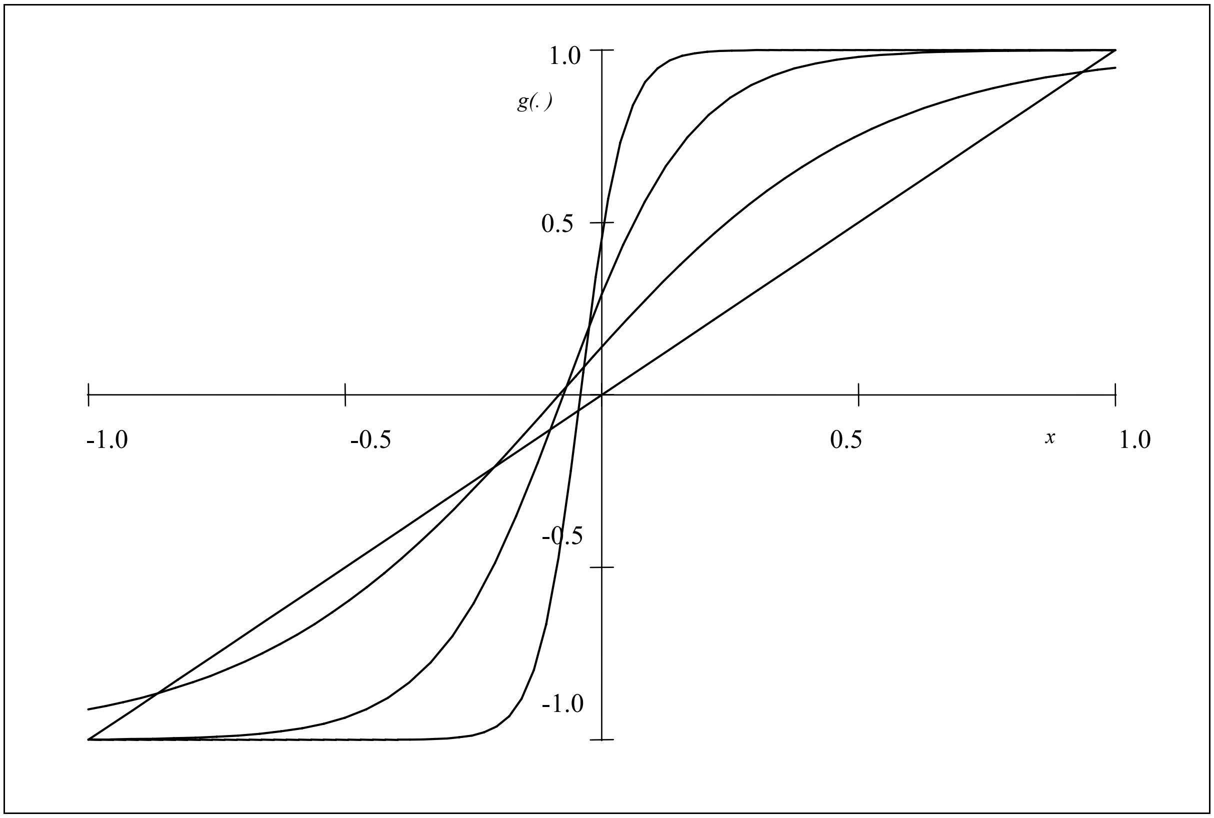
the"net choice for +1". If the net choice is unity, all are choosing +1; if the net choice is zero, then 1/2 are choosing +1 and 1/2 are choosing -1; if the net choice is -1, all are choosing -1. In the science theory choice context equation (2.9) says that the net choice in period *t* is deterministically related to the net choice in period *t-1*, i.e.

(2.12) $a(t) = g\big(a(t-1); b, h, C\big)$

for the deterministic function g given by (2.9) above. The equation (2.12) has been written using notation that draws attention on the role of the three key parameters, the intensity of choice b, the difference in the systematic parts of the utilities, h, and the size of the peer effect, *C*. These three parameters determine the "shape" of the function *g(a(t-1);b,h,C)* as a function of *a*.

The graph of *g*, Figure 1 below, depicts the function *g* and shows how the shape of the function changes as the key parameters change. Notice how the graphed function looks like a low sloping grade for small values of *b* and *C* but assumes a steeper grade as *b* and *C* increase and finally becomes a sharp "cliff" as *b* and *C* become very large. It is this behavior that generates the alternative stable states, which are represented by points crossing the 45-degree line on Figure 1.

Figure 1



System (2.12) is a simple deterministic difference equation to analyze. The function *g* increases as *a(t-1)* increases for all positive values of *b*. An increase in *h* shifts the function up and this generates a bias towards +1 as h becomes positive and increases. If there is no bias, i.e. *h*=0, an increase in *b* "twists" the function around the value zero and it becomes a sharp threshold increase from -1 to +1 as *a(t-1)* moves from negative to positive no matter how small a move it makes. Also note that if *b*=0, *g(a;0,h,C)*=0 for all *a*'s so (2.12) just stays at the fixed point *a(t)*=0 and the net choice is always zero. This makes sense: on the one hand, if each agent simply randomizes over the choices -1,+1 with no bias towards either of them, one would expect the system to settle quickly to a community net choice of zero, i.e. 1/2 of them choosing -1, 1/2 of them choosing +1; on the other hand if choice is extremely precise, i.e. *b* is huge and positive, then even a tiny amount of peer pressure, *C*>0, can create "social traps" at both -1 and +1, even when *h* is positive. For example, if *a(t-1)* is near -1, and

(2.13) $h+Ca(t-1)<0$,

the system remains "stuck" at a point near -1 at date t, if $a(t-1)<0$, even though choice +1 is preferred because $h>0$.

If the community size N is very small there is randomness in the behavior of the community wide net choice a(t) that we have ignored. As the community size increases then the Law of Large Numbers asserts that the deterministic system we studied above becomes a good approximation.[vi] The system's behavior can be very different if the group average is treated as a random variable, which it is in reality. More will be said about this difference later. As we illustrated above, the dynamics of $a(t)$ given by equation (2.12) above can display alternative stable states which are "sticky" in the sense that once in a stable state, it is difficult to escape. We sum up the discussion at this point into

Result 2.1: Let group size N become increasingly large. At each moment the average choice, $a(t)$ satisfies (2.12) if at each date t, each member of the group expects that $a_i(t)=a(t-1)$. If the group holds rational point expectations, meaning that they all share the same forecast of next period's $a(t)$ and it turns out to be correct, then all rational point expectations must satisfy the equation,

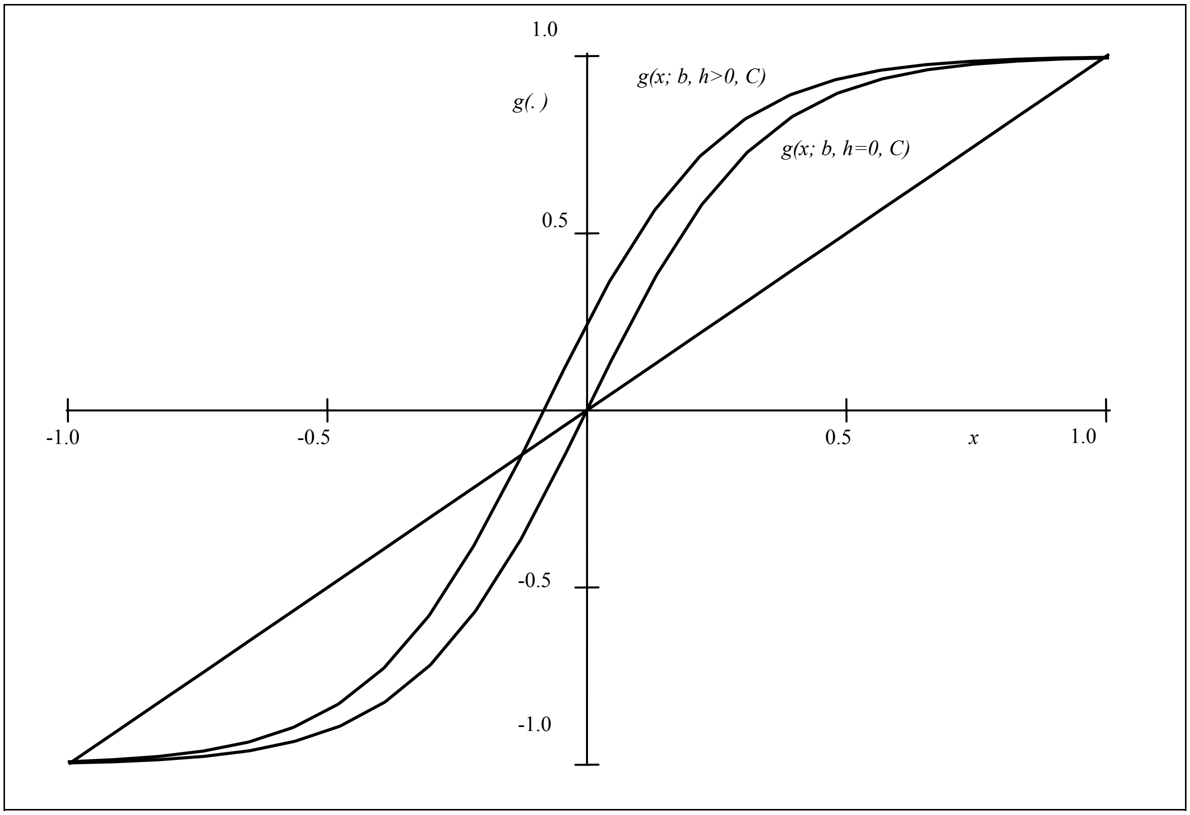
(2.12.RE) $a^*=g(a^*;b,h,C)$, over all time periods.

This stable solution is unique if bC is small enough and it is one of two (locally stable) solutions of equation (2.12.RE) if the absolute value of h, $|h|$ is small enough and bC exceeds a threshold value. It also is unique if $|h|$ is large enough. This result is obvious as can be seen by looking at Figure 2 below, which plots the function $g(x;b,h,C)$ as a function of x. Note the following properties:

(i) the function $g(x;b,h,C)$ increases in x first at an increasing rate then at a decreasing rate for all values of b, h, C;

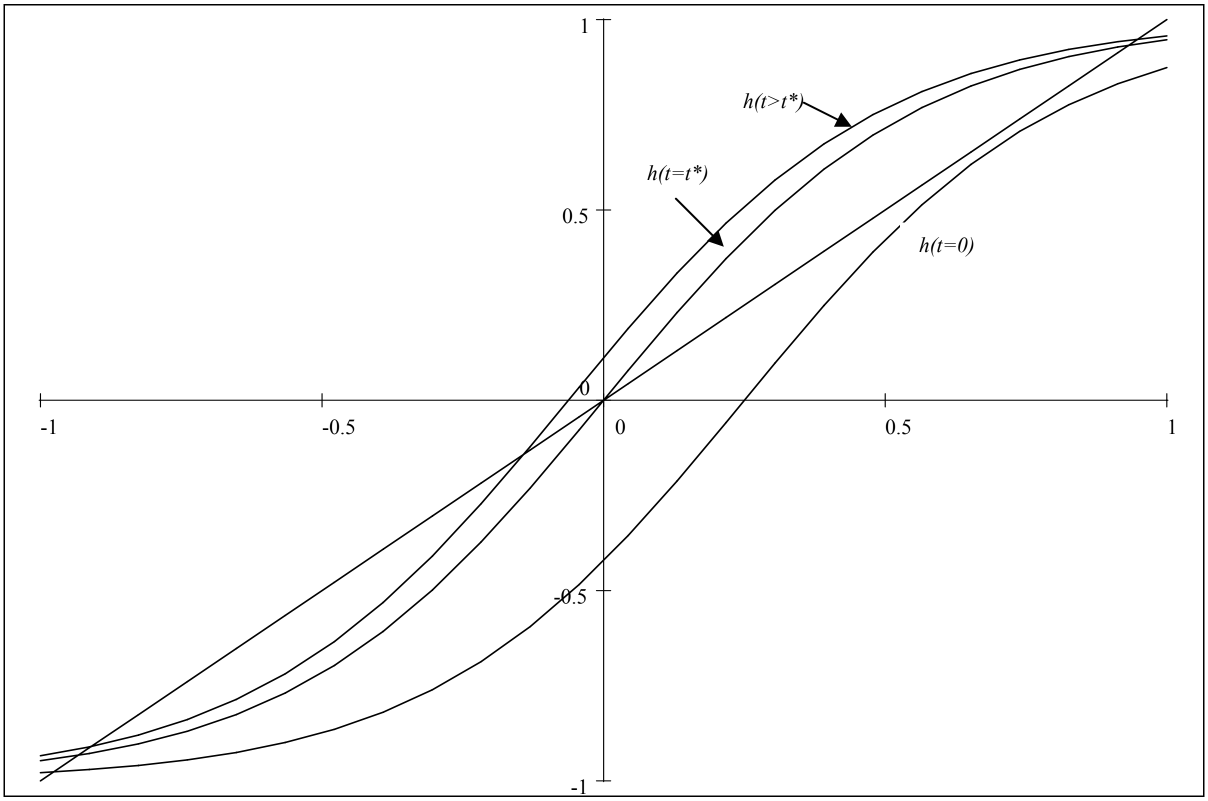
(ii) function $g(x;b,h,C)$ is zero at $b=0$ for all values of h,C;
(iii) at infinite b, for $h=0$, function $g(x;b,h,C)$ is minus one for negative x, is equal to zero for $x=0$ and is unity for x positive. Thus, Figure 2 shows that for h=0 the function crosses the 45degree line at three points when b is large enough.

Figure 2



Therefore, if bC is large enough, there are alternative stable states for the difference equation (2.12) when h is close enough to zero. Consider the following example. Suppose h has been negative at a constant value for a while so that the current equilibrium is negative. Let now $h=h_t$ gradually increase, becoming zero for the first time at time t^* and continuing to increase for $t>t^*$. The social optimum is for a switch to occur at $t>t^*$, when the intrinsic value of decision +1 becomes superior. But it is easy to see from graphing the dynamics that the system is trapped (for the case where bC is large enough) in a negative stable state, in which the option –1 continues to be chosen. There are three steady states (i.e. fixed points of the dynamics (2.12)). The middle one (the locally unstable one) blocks progress towards the socially desirable positive steady state. See Figure 3 below.

Figure 3



In the science paradigm case this outcome represents the sluggishness of the scientific community in adopting a better paradigm because of peer effects created by the past dominance of the old (now inferior) paradigm. The superiority of the new paradigm *h(t)* must increase to a rather large positive critical value before a "window" is opened up through which the dynamics can "escape" the low level "trap" and evolve towards the better choice. As *h* continues to increase the dynamics now moves rapidly towards the positive alternative stable state. Once the dynamics is in the basin of attraction of the positive steady state, it will stick there even if a new paradigm appears to assume the role of +1 and the current newly established paradigm plays the role of -1. This type of dynamics requires a big push to get the system out of an historically determined locally stable state towards an alternative that is now superior.

We turn now to a type of dynamics that is not sticky but where the stable states satisfy the same equation as (2.12.RE).

Statistical Mechanics and Social "Phase Transitions": Escape from "Stickiness"

The second treatment will be less familiar to economists. It takes into account the fact that a(t) is a random variable that induces correlations among the agents' choices because of peer effects indicated by *C.*. Interactions between these correlations and the intensity of choice *b* produce dramatic differences in the dynamics from the system above. That system assumes that, conditional upon expectations of *a(t)*, which we denoted by $a_i(t)$, the choice made by agent *i* is independent of other agents' choices. This assumption ignores the fact that since *a(t)* is the average of all agents' choices and *a(t)* influences each agent's choice, agents' choices are therefore correlated if their number is not large. Modeling this correlation in a tractable way that yields Laws of Large Numbers and Central Limit Theorems is a challenge. One way to do it draws upon results in statistics and statistical mechanics.

As a consequence, Equation (2.12.RE) will be replaced by a result that gives the same equation for the stable states, a^* but will lead to different behaviors if there are multiple roots of equation (2.11.RE). If *h* is not zero the root selected will be the one with the same algebraic sign as that of *h*. If *h* is zero a mixture equal to 1/2 times the negative root plus 1/2 times the positive root will be selected. Therefore, if *h* changes sign (no matter how small its absolute value) there will be an abrupt and truly discontinuous change that we shall call a social phase transition, using the language of statistical mechanics. Modeling such a system will provide a sharp definition of a social discontinuity that contrasts with an escape from the attraction basin of an alternative stable state, as modeled in the initial system. Some mathematical notation is needed to state and explain this result. Less mathematically inclined readers can just skip to the following verbal explanation.

3. Minimal Models of Social Choice Dynamics: Social Phase Transitions

We can focus attention on a single point in time and drop "t" from the notation in order to simplify it. Then, we formulate a probability model:

$$(3.1) \quad P\{(\omega(1),\omega(2),\ldots,\omega(N))\} = \frac{\exp[bU]}{Z},$$

(3.2) $U = \sum_{i=1}^{N}\left[u(\omega(i)) - C(\omega(i) - a^*)^2\right],\ a^* \equiv \frac{1}{N}\sum_{i=1}^{N}[\omega(i)],$

(3.3) Z= a normalization factor

that makes the sum of P over all 2^N configurations of the N agent's choices between +1 and -1 equal to unity, as required in a probability distribution. Equation (3.1) represents the probability of the particular social configuration of agents' choices $(\omega(1),\omega(2),...,\omega(N))$. Since each agent has two choices, -1 or +1 and there are N agents, there are 2^N of these possible configurations. As before, $C(\omega(i) - a^*)^2$ represents the "punishment" for deviating from the group average. However, now a^* is the random variable given in (3.2) instead of a deterministic belief about the large system value of the group average assumed in Section 2. The quantity U should be regarded as a systematic part of the utility of the group, rather like that of a social planner acting for the group as a whole (Brock and Durlauf (2001a)). The intensity of choice "b" now refers to the random part of group preferences instead of the random part of preferences of each individual agent as in Section 2. As we shall see below the system (3.1), (3.2) generates very different behavior as N increases even though the equation for the limiting behavior of the average is unchanged from that in Section 2. Consider the simplest case of no heterogeneity in preferences, i.e.,

(3.4) h_i=h, for all i=1,2,...,N.

Since $\omega^2 = 1$ a little algebra can transform (3.1) into the form,

$$(3.5)\quad P\{(\omega(1),\omega(2),...,\omega(N))\} = \frac{\exp\left[b\sum_{i=1}^{N}(h + Ja^*)\omega(i)\right]}{Z},$$

where the normalization factor has changed but we still call it Z and J=$2C$.
It turns out that the limiting value of the group average, "a", satisfies,

(3.6) $a=g(a,b,h,2J)$,

where g is the same function as in (2.12) above, and where the starred solution a^* is the solution of (3.6) with the same sign as h when there is a choice of multiple solutions of (3.6).

The reason why the quantity "$2J$" appears in (3.6) instead of "J" as in (2.12.RE) is because (3.1) and (3.5) takes into account the fact that each agent i impacts all other agents and each of those other agents also impacts i. The model considered in (2.12.RE) is like a non-cooperative game in which each agent only takes into account the impact of the other agents upon his or her decision. Hence a "2" appears in (3.1) and (3.5).[vii]

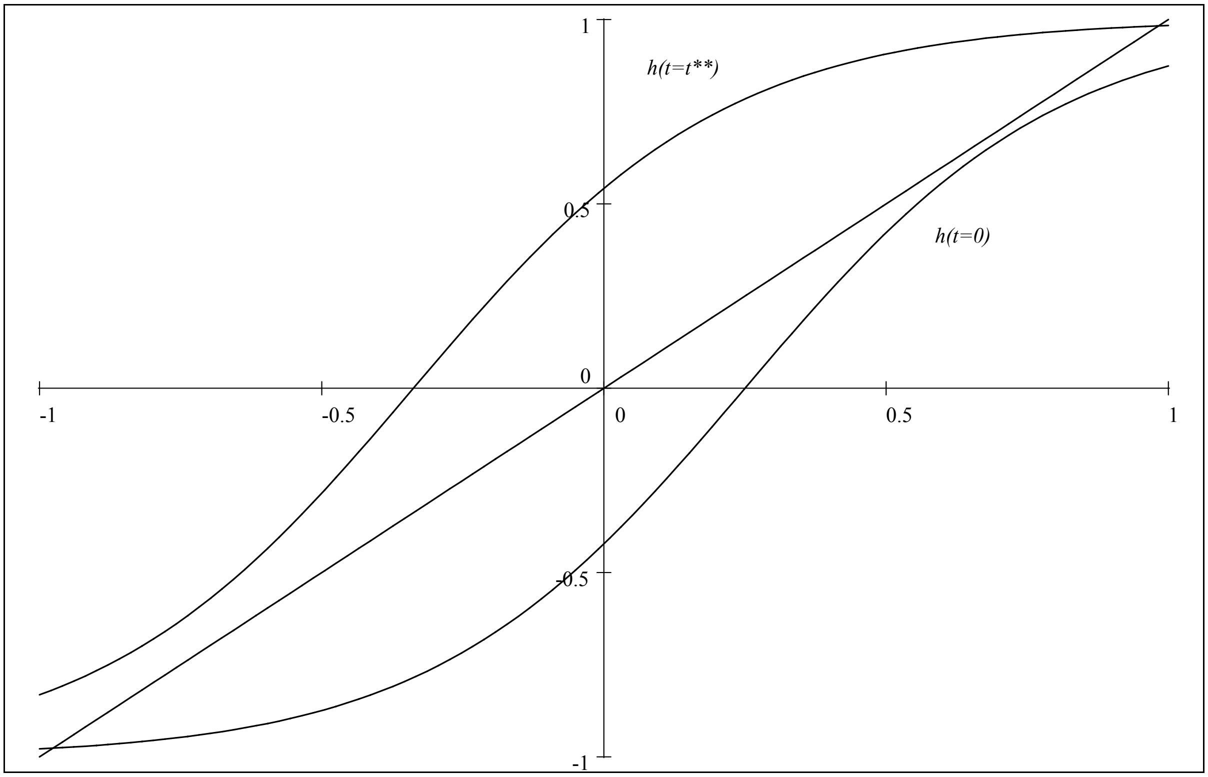
It turns out that the correct choice among solutions that satisfy (3.6) is the one that maximizes the limiting "inclusive value" per capita (BD(2001a, p. 257)). This is defined by $v(N)=V(N)/N$, where $V(N)\equiv E\{\max U(\omega)\}$, the maximum expected utility over all social configurations. This is the discrete choice analog of the usual net benefit per capita of conventional welfare analysis (ADT (1992), BD (2001a)). In the discrete choice case, randomness adds a new term to inclusive value. Inclusive value collapses to the conventional welfare measure when the intensity of choice, "b," is infinite, since then choices correspond to the conventional deterministic case.

For $bJ>1$ the limiting inclusive value per capita has two local maxima. The global maximum shifts from the negative one to the positive one as h passes through zero from negative to positive. This corresponds to a dramatic change in dynamic behavior from the case in Section 2 above. In this present case there will be a sharp discontinuity in group behavior. We summarize the discussion up to this point by stating

Result 3.1: Let $bJ>1$ and let $h\equiv h(t)$ slowly increase from negative to positive as t increases. That is, suppose $h(t)<0$, for $t<t^*$ and $h(t)>0$, for $t>t^*$. Then $a^*(t)$ is the negative solution of (3.6) for $t<t^*$, and $a^*(t)$ jumps to the positive solution of (3.6) for $t>t^*$. Hence, for the case $bJ>1$, the group consensus choice jumps discontinuously from the smallest solution of (3.6) to the largest solution of (3.6) the moment h passes from negative to positive. Similarly, if h slowly decreased from positive to negative there would be a discontinuous drop from the largest solution of (3.6) to the smallest solution of (3.6). In the case $bJ<1$ there is only one solution of (3.6) and no such discontinuity in the dynamics appears as h passes from negative to positive or vice versa.

In terms of the scientific paradigm example, this implies that as soon as the new paradigm had overtaken the older one in terms of its perceived intrinsic merit, the scientific community would immediately shift to a new strong consensus in its favor. This behavior contrasts sharply with the behavior in the initial model even in the case of rational expectations. In that case, $a^*(t)$ is stuck at a negative solution of (3.6) until $h(t)$, the perceived intrinsic merit, becomes so large and positive at time t** that the graph of (3.6) is lifted high enough so that the middle solution of (3.6) disappears to open a "window" so the dynamics (3.6) can "tunnel through" towards the desirable positive solution. See Figure 4 below. To put it another way the "dead hand" of history lies heavily on the dynamics in Result 2.1 but the dynamics of Result 3.1 escapes the "dead hand" of history and are able to react immediately to what is socially optimum currently. We call dynamics of Result 2.1, "mean field" dynamics because these dynamics result from agents forming point expectations of the system-wide average, which is really a random variable. Point expectation formation shuts off the correlations in the Result 3.1 dynamics so the phase transition property of Result 3.1 is lost.

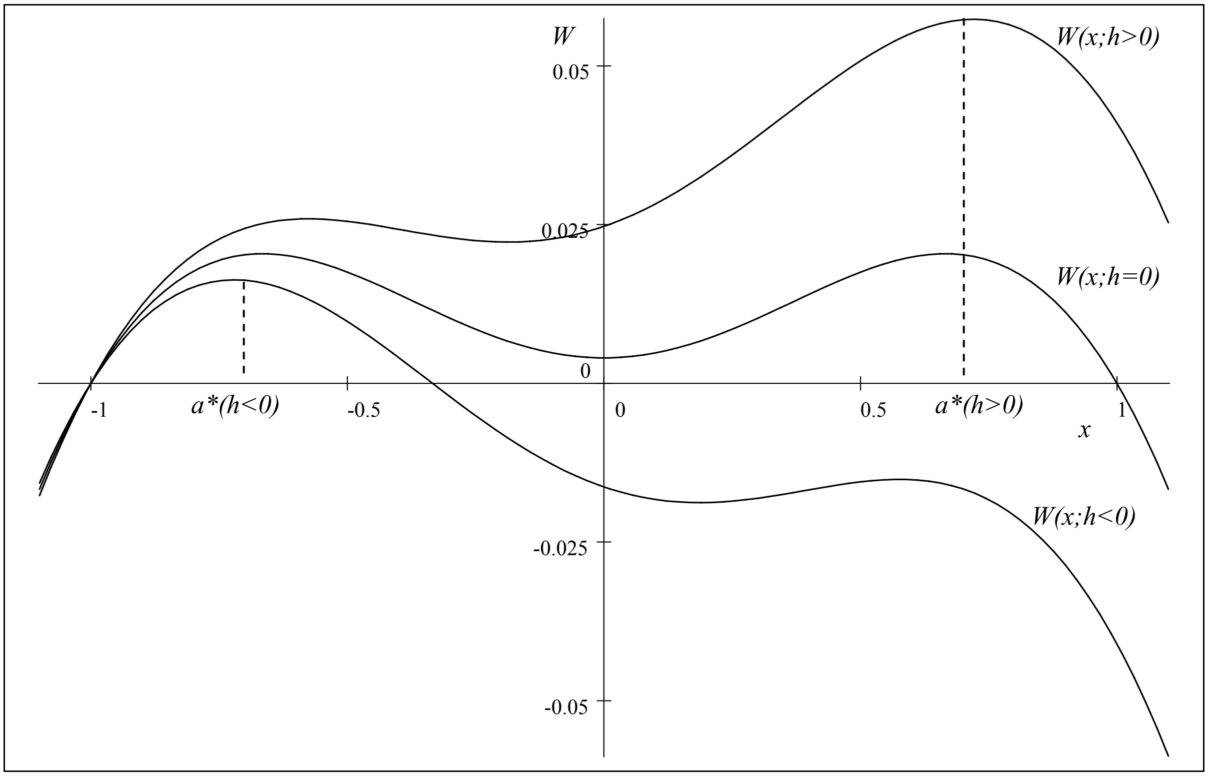
Figure 4



What is the source of the dramatic difference between Result 3.1 and Result 2.1? The easiest way to understand this difference is to recall that the correct choice of the solutions that satisfy (3.6) is the one maximizing a function that appears when computing the limiting "inclusive value" per capita (BD(2001a, p. 257)). Call that function $W(\{H_i(t)\},x;b,J)$ the limiting inclusive value per capita. Here x represents variable values of a, the group average. Consider the simplest case, in which $H_i(t)\equiv h$ for all agents for all dates and $W\equiv W(h,x;b,J)$. The function W has multiple local maxima in x when $bJ>1$. The limiting value of the average choice of the community, namely a^*, is the global maximum of W. When $H_i(t)\equiv h=0$ for all agents, and $bJ>1$, the limiting inclusive value per capita, $W(0,x;b,J)$, has two global maxima, one positive and one negative. The limiting value of a^* is a mixture with 1/2 of the mass on each of the two global maxima. When $H_i(t)\equiv h$ becomes slightly positive, the positive global maximum value of W is slightly bigger than the negative one, so the limit value a^* "leaps" from the mixture to putting all mass onto this positive and unique global maximum. If "h" now becomes slightly negative, the new global maximum is the negative one, so a^* "drops" discontinuously to the negative one.

One can imagine an undulating surface with two local maxima, the larger of which always being chosen at each point in time. See Figure 5.

Figure 5



The correlation among agent's choices can lead to rapid shifts in response to changes in underlying "fundamentals", whereas Result 2.1 works more like a non-cooperative game that can get stuck in a bad equilibrium or in a good equilibrium. However, if parameters such as b or C slowly diminish so that the Result 2.1 system moves to a configuration that has only one equilibrium position, then rapid change can occur when multiple equilibria are replaced by a unique equilibrium.

How might one be able to apply these concepts to detect such an impending "tip" in the field? How might one be able to detect in practice the difference between a process governed by Result 2.1 and one governed by Result 3.1? . Also, could one use these results to help predict an emerging tipping point or another abrupt change, social phase transition, or regime shift?

These questions are very hard.[viii] Attempting to predict a tipping point is rather like a doctor attempting to predict the exact moment a patient in bad cardiac health will have a heart attack. She can only indicate that the patient has characteristics that suggest a heart attack will happen with high probability. She cannot say exactly when it will happen.

Result (3.1) suggests potential routes to making a social system more nimble and less sticky by strengthening the correlations amongst agents' actions[ix]. This amounts to increasing positive feedbacks, either by reducing random variability in agents' choices or by increasing penalties for deviation. . In principle, the strength of a positive feedback loop like that induced by a large value of "*C*" in our model could be measured by survey methods designed to elicit from agents how much they feel that they would be punished if they deviated from the group average. We will say more about the use of our type of modeling in an attempt to link observable quantities to impending rapid shifts below.

Turn now, however, to another result that will probably not be familiar to social scientists. Social scientists are familiar with normal distributions. Most social scientists are familiar with Central Limit Theorems that show that a normal distribution is the limit for appropriately scaled sums of random variables. But in settings like Result 3.1, limiting distributions with "fatter" tails than normal will sometimes emerge. Baumgartner's paper in this volume provides empirical support for this proposition, finding that extreme environmental policy events occur more frequently than would "normally" be expected.

We have,

Result 3.2 (Adapted from Amaro de Matos and Perez (1991)): Assume that $bJ>1$ and that the variance of the distribution of $\{h_i\}$ across agents is finite for each date t. We omit t in the notation but make the size of the community, N, explicit. We define a random variable X for each date t,

$$\frac{\sum_{i=1}^{N}[\omega(i)-a^*]}{N^{1/2}} \to X ,$$

Here the random variable X is distributed as a mixture of normal distributions and the quantity a^* maximizes an inclusive value expression analogous to that in the case where all h's are the same.

The limiting behavior of this normalized sum of deviations from the mean is "unconventional" for the case $bJ>1$. A very small peer effect C can interact with a large intensity of choice to make $bJ>1$ so not only does the "leaping" behavior of Result 3.1 emerge but also the unusual limit distribution of normalized sums. This limit distribution has fatter tails than the normal distribution, implying that extreme events are more frequent than would "normally" be expected. This result may lurk behind the common observation in social sciences of large variation in behavior across measurably similar communities and social groups. However, if $bJ<1$, the limit distribution X is normally distributed.

Effects of Slow Dynamics of $\{h_i(t)\}$, b, J.

Results (2.1) and Results (3.1), (3.2) shed light on what can happen as the result of gradual changes in $\{h_i(t)\},b,J\}$. Recall that "b" measures the intensity of choice. A common strategy in policy debates appears to be one that lowers b and biases the h's away from the "truth" by sowing confusion about the issue and making false claims. For example, in the evolution of understanding of lake eutrophication and of the role played by phosphorous, "scientists" working for special interests muddied the waters by trying to direct attention towards other superficially plausible alternative causes.

We can model this activity as a special interest group induced decrease in "b" as well as an induced bias in the distribution of h. Clearly, if such activity keeps $bJ<1$ and $h<1$, social action towards the desirable equilibrium will not crystallize and there will not be a phase transition like that of Result 3.1 to escape from a low level equilibrium trap created because the system is in the basin of attraction of an inferior but locally stable steady state. To put it another way, "b" is high when "transparency" of understanding of an issue is high. Transparency can be muddled and decreased by "junk science" funded by special interest groups, which, if successful, can create policy inertia. This seems to have happened on the issue of global warming, as suggested by the Lane paper in this volume, particularly because the effects of climate change remain mostly in the future and hence are not self-evident to non-scientists.

On the other hand, transparency can be increased through dynamic and forceful scientific leadership and public education campaigns to clear away junk science and illuminate good science. Reputable scientific organizations like the National Academy of Sciences can play a major role in increasing "b" as well as removing bias in $\{h_i(t)\}$ provided they can get their message through the fog of commercial media. Public media such as National Public Radio and the Public Broadcasting System can play a key role here.

If "b" is very large, a very small amount of peer pressure (induced perhaps just by people communicating through their social networks) can cause bJ to be larger than unity. Politicians have begun using the Internet extensively to promote interactions among their "base" constituency in order to reinforce their support. This cuts both ways. Notice that $bJ>1$ helps the system jump quickly to the current social optimum in the case of Result 3.1's dynamics, but it can hurt the welfare properties of the system's dynamics by making them sticky at the inferior basin of attraction due to history (path) dependence in the case of the dynamics of Result 2.1.

Models of changing correlations that generate phase transitions rather than "mean field" models may better represent situations where conditional independence is replaced by dependence. Dependence can be created by "leaders" (which could be media coverage rather than individual activists or policy entrepreneurs) who are exceptionally persuasive to individual agents $i=1,2,...,N$ and, hence, are effective in coordinating their actions. Probability models of the form (3.1) and (3.2) are a useful way of capturing the effect of such leaders in inducing or increasing correlations amongst individual choices as well as their effect in increasing "transparency" (which can be modeled as increasing the "intensity" or "precision" of choice parameterized by "b" here). The implication is that effective leaders may be able to bring about rapid and discontinuous, even revolutionary, phase transitions.

Reality is probably better presented by a combination of models which yield the same set of roots but have some probability "p" of being able to jump across a negative basin of attraction to a positive one as h changes from negative to positive, where changes in p affects the degree of stickiness. For example, $p=0$ could represent the dynamics of Result 2.1 and $p=1$ could represent Result 3.1.[x]

Of course, what is important is not an abstract device like that but what such modeling can teach us about reality. What evidence would reveal that a particular social process is more like Result 2.1 than Result 3.1? In the former, each agent acts independently, after forming an expectation about what the group will do and the resulting peer effect on her, with the expectations being fulfilled in equilibrium. In the latter, the process unfolds as if some mechanism chose the configuration of group actions that optimized group welfare, respecting each agent's own objective but penalizing her deviation from the group average. In both cases there may be multiple equilibria but in the former, no mechanism is assumed that would lead to the best one.

What observable indicators or signatures might tell us which dynamic is actually operating? One approach mentioned above is to look for direct evidence from surveys that ask people whether they have incentives to choose actions being chosen by others in the group and whether those incentives would change if the group chose opposite actions. A second is to look for indirect evidence such as observations of large variation of group outcomes across groups that seem homogeneous with respect to relevant characteristics

Possibly, we might expect a dynamic like Result 3.1 to operate in situations where a leader can coordinate the preponderance of agents onto the best equilibrium but a dynamic more like Result 2.1 in situations where factional leaders compete or where no one or nothing plays the role of coordinator.

We are now ready to ask what insights these models can offer in understanding the punctuated policy equilibrium phenomena discussed by Baumgartner (2003) and in building models that illuminate what Jones, Baumgartner,and True (2002), JBT (2002), call policy macro-punctuations. For example, JBT (2002) use a large data set for U.S. government budgetary changes to show that

(i) There are "a limited number of distinct macro-punctuations in government budgeting that respond to a combination of external shocks and internal dynamics."

(ii) There is "a pattern of punctuations that cannot be explained by typical political and economic factors: partisan control, public opinion, and economic growth."

(iii) There is "considerable year-to-year volatility in the funding of government programs even in the absence of macro-punctuations."

(iv) There is "a substantial and distinct decline in budget volatility in the post-war period."

Suppose we model action on a particular item in the federal budget as -1 for the status quo and +1 for a change away from the status quo and let $H_i(t)$ denote the difference in preference for legislator i for this particular item at date t. Our first type of model (Result 2.1) produces alternative stable states by the internal dynamics produced by penalties from deviating from the group position. The same dynamics can result if one legislator's benefit is increased when more other legislators take the same action. Since both mechanisms produce positive feedbacks, it is not surprising that they generate similar results. In general, similar dynamic phenomena can be expected in diverse settings where forces of conformity or complementarity are present. If such forces are strong enough and the intensity of choice is high enough so that the product, bJ, crosses a threshold, the status quo for the particular budgetary item or particular policy issue would prevail, unless the preference $H_i(t)$ changes dramatically away from the status quo for many legislators at the same time. Since such an event would be rare, macro-punctuations would occur infrequently.

Consider finding (ii) above. The internal dynamics caused by $bJ>1$ in our model tells us that there will be times when the status quo has been protected by negative feedback forces of conformity or complementarity, even as $H_i(t)$ trends up away from the status quo for a substantial number of legislators. Result 2.1 suggests that occasionally (possibly quite rarely) the basin of attraction of the smaller stable state, maintaining the status quo, is escaped by the dynamic process, at which point a macro-punctuation would ensue that might appear inexplicable by the policy "fundamentals" listed in finding (ii).

Public opinion, "policy learning" or economic change might affect the preferences $H_i(t)$ of each legislator but it might surprise an observer to see the legislature respond dramatically, i.e. a macro-punctuated response, to a seemingly small additional change in the $H_i(t)$, as the U.S Congress did in dropping the ITQ moratorium, as recounted in the Repetto & Allen chapter. But the interaction between internal dynamics caused by conformity/complementarity effects together with external changes "driving" the system can produce these dynamics. Slow moving variables, whether social, economic or demographic, may drive the values of the $H_i(t)$ to a point where some kind of "threshold" is crossed.

Baumgartner (2003) discusses the following empirical signatures consistent with complex dynamics in policymaking processes:

(i) The tone of media coverage of pesticides trended from mostly positive to distinctly negative, with a rather sharp drop in the 1950's when an upward trend in total coverage occurred.

(ii) Budgetary changes in the U.S. Federal budget over the period 1947-2000 have thicker tails than a normal distribution would.

(iii) In a sample of issues in 1996 Baumgarter's team found that the number of lobbyists is highly skewed across issues, with one single issue occupying 17 percent of lobbyists.

(iv) The number of anti-death penalty stories showed no trend over the period 1960-1998 but jumped abruptly up in 1999.

All such phenomena could be generated by appropriately parameterized versions of our models. Although it would be a full research project to build models that fully explain the findings of teams such as Baumgartner's in policy science, we hope to have said enough to indicate the potential usefulness of the kind of modeling presented in this chapter.

4. Concentrated Special Interest Groups Versus Diffuse Groups

Next, models are presented that focus on the structure of social interaction within groups in producing pressure on policy makers and political systems. The models discussed above are much too simple. Most policy changes produce losers and winners but the initial models only had one group, winners, and the models explained how the system could get stuck in an inferior equilibrium. The goal was to identify leverage points for actions to tip the system out of a bad equilibrium towards the better equilibrium.

The much harder and more important problem is to model the problem of inducing policy change when the benefits to change outweigh the losses but the losers are better organized for collective action than the winners.[xi] Fortunately, the simple binary discrete choice models introduced above can still be used to model the movement of an agent i from a state of "latency" (which we denote by -1) to "entering the game" (which we will denote by +1). This leads to a "two stage" game in which the first stage is the decision whether or not to enter the game and the second stage is the choice of the magnitude of effort to expend after entry. The goal will be to understand the ability of concentrated special interest groups to mobilize action and to deliver more action than diffuse groups.

Definition 4.1: A special interest group is a group that is proposing to use or is currently using the government to obtain a benefit, B where the cost to the whole society of giving this benefit is $C>B$..

Examples include: (i) tariffs, export subsidies and other "protective" measures, where the cost of such benefits to the public is greater than the benefits received by the industries sheltered from competition; (ii) subsidies to agricultural interests, where the costs to the public exceed the value of the agricultural subsidies; (iii) the assignment of water "rights" to agricultural interests whose water uses are less valuable than alternative uses (Milgrom and Roberts (1992), Chapter 9); (iv) grazing rights and timber concessions on public lands awarded at subsidized rates, reducing public revenues and increasing ecological damages. The general pattern is that of "rent-seeking behavior", wherein one group use the political system not only to take resources from the rest of society but also, in many cases, to impose deadweight losses on others that may even be larger than the value of the resources they capture.

Suppose we define politics as authoritative allocation of value and economics as competitive allocation of value. A common interest group mustering political pressure faces the same structural problem as a group mustering the power to police its jointly owned common property or any group organizing to provide a commonly supplied local public good for itself. A key problem is that the group must be able to police free riders effectively to ensure that each member contributes to the joint effort. The superior ability of concentrated groups to wield political power might be due, for example, to characteristics of their livelihoods that enable them to organize more effectively, to police free riders and to muster resources to pressure the political system: Members of the group might in a repeated economic relationship with fellow members. For example, local lobster fishermen deliver to the same markets, share the same docks and work the same coastline. Also, members of the group might need access to a common joint factor of production for which there are no close substitutes. For example, surgeons need access to operating rooms at the local hospitals and the good will of fellow physicians for referrals. Real estate agents need access to the formal network of the Multiple Listing Service as well as their informal network (aka "social capital").

This rent-seeking dilemma has much the same analytical structure as the prisoner's dilemma studied by Axelrod (1984), (1997).[xii] Organizing a political pressure group is structurally similar to self-organizing a group to provide a public good for the group use or to manage a common property resource. Ostrom's (1990) message is that, contrary to the metaphor of the "tragedy of the commons", many groups have successfully self-organized workable management of their commons without the intervention of a central authority. This optimistic message that groups can and do self-organize to solve commons problems implies that special interest groups are also able to solve their own "commons problem" of self-organizing and applying political pressure to capture authoritative allocations of value. The general finding is this: groups that are compact, homogeneous, and whose actions are internally transparent tend to get political benefits that are less than their cost to the diffusely organized public. Therefore, only such groups are defined as "special interest groups."

Ostrom identified group characteristics that help predict the likelihood of successful self- organization:

(i) Groups self-organize best to manage common property resources (CPR) when they can (1) define access conditions, (2) regulate appropriation in terms of quantity, space, or technology, (3) monitor and enforce these rules, and (4) "...when boundary, authority, monitoring, and sanctioning rules are defined and enforced internally, the outcomes are likely to be more efficient than those achieved when the rules are imposed externally". (OGW (1994, p. 316)).

(ii) CPR problems are easier to solve when "the costs of obtaining relevant information about both the resource facility and the flow of resource units are relatively low in comparison with the benefits that can be achieved through successful institutional design." (OGW (1994, p. 316)).

(iii) "Simply allowing individuals to talk together is change enough in the decision-making environment to alter behavior substantially, even though promises made without external enforcers are theoretically considered to be irrelevant." (OGW (1994, p. 320)).

(iv) Repeated interaction in the expectation of mutual trust assists in overcoming "social dilemmas" (OGW (1994, p. 328)).

(v) No use of trigger strategies, such as “tit for tat”, is observed in either the field or the lab, contrary to conclusions of many repeated-game models of the resolution of social dilemmas (OGW (1994, p.301).

A simple way to analyze the contest between concentrated versus diffuse groups is to use "action supply functions" on both sides of the struggle.[xiii] Consider two groups, "gainers" (group 1) and "losers" (group 2) who supply pressure on the political system for and against policy at level $T(t\text{-}1)$ at date t according to

$$(4.1)\quad x_i(t) = F\big(S_i\big(t;T(t-1)\big), X1_i(t), Y1_i(t); a, b\big)$$

$$(4.2)\quad y_j(t) = G\big(C_j\big(t;T(t-1)\big), Y2_j(t), X2_j(t); A, B\big)$$

where $x_i(t)$ and $y_j(t)$ are individual contributions by gainer i and loser j at date t, $S_i(t;T(t\text{-}1))$. $C_j(t;T(t\text{-}1))$ are gains and losses to gainer i and loser j when policy is set at level $T(t\text{-}1)$. Also, $X1_i(t)$, $Y1_j(t)$ are member i's expectations regarding total contributions by the rest of group 1 and expectations of i regarding total contributions in group 2. Similar interpretation holds for $Y2$ and $X2$. Furthermore, a, b and A, B denote effectiveness and noticeability parameters perceived by individual members of groups 1 and 2. Here, a member's contribution F is assumed to increase with the payoff S, increase with the expected contribution of other group members $X1$, and decrease with expected competing contributions $Y1$. F is also assumed to increase with effectiveness a and noticeability b even if S is small relative to the cost of individual effort for i. This last assumption captures the idea of "noticeability" of i by other members of the group. Similar properties hold for G. Assume that[xiv]

$$(4.1')\quad x_i(t) \;\text{ solves }\; \left\{ S_i\big(t;T(t-1)\big)\left[\frac{a}{\big(x + X1_i(t)\big)} + \frac{b}{x}\right] = 1 \right\}$$

$$(4.2')\quad y_j(t) \;\text{ solves }\; \left\{ C_j\big(t;T(t-1)\big)\left[\frac{A}{\big(y + Y2_j(t)\big)} + \frac{B}{y}\right] = 1 \right\}.$$

If one solves for Nash non-cooperative equilibrium to get reduced form supply functions, then for a plausible set of game theoretic structures, it will be true that

(i) If the total stakes for one side increase, that side applies more pressure.

(ii) If the total stakes on one side remain constant but its distribution among the group's members becomes more unequal (more concentrated), then that side applies more pressure.

This analysis can be easily extended to include cases where there is a slow moving variable, such as a slow erosion of political power by one side of the struggle. The predicted result can be an abrupt change in the outcome, related to shifts in the relative contributions of contending groups. This may be hard to link to observable "fundamentals", much like the "surprises" caused by a slow moving variable in previous models. Empirical work in this area has had mixed success due to the presence of many confounding events and political forces that make it difficult to isolate the effects of interest group pressure on the political outcome.

Building on the previous assumptions, the political system is assumed to choose the policy outcome *T(t)* according to

(4.3) $T(t) = P(T(t-1), X(t), Y(t))$

where

(4.4) $X(t) = \sum_{i=1}^{N1} x_i(t)$, $Y(t) = \sum_{j=1}^{N2} y_j(t)$,

Here the function P is assumed to increase in *T(t-1)* and *X(t)* and decrease in *Y(t)*. That is, the policy outcome is influenced by the magnitude of contributions of the two contending sides but there is an in-built momentum to policy decisions.

Assume that payoffs S and C are equal across all i and j respectively, assume rational point expectations and use (4.1'), (4.2') to obtain

(4.1") $x(t) = S(T(t-1))\left[\frac{a}{N_1} + b\right]$, $X(t) \equiv x(t)N_1 = S(T(t-1))[a + bN_1]$

(4.2") $y(t) = C(T(t-1))\left[\frac{A}{N_2} + B\right]$, $Y(t) \equiv y(t)N_2 = C(T(t-1))[A + BN_1]$,

(4.5) $T(t) = P(T(t-1), X(t), Y(t))$.

Social welfare at t is given by

(4.6) $W(T(t-1)) \equiv N_1 S(T(t-1)) - N_2 C(T(t-1))$

which we assume is optimal at *T=0*. Make the natural assumption that *S(0)=C(0)=W(0)=0*. We obtain via substitution a "reduced form" dynamic equation for the time path of policy outcomes,

(4.7) $T(t) = F(T(t-1)) \equiv P(T(t-1), S(T(t-1))[a + bN_1], C(T(t-1))[A + BN_2])$.

Even though this formulation is simple, it is useful for focusing attention on what forces impede optimum policies. Optimal policy is *T*(t)*=0 for all *t*. Bad policy is positive *T*. We are interested in locating conditions for (a) emergence of bad policy from a baseline of zero, (b) eliminating bad policy once entrenched. They are:

(i) Good policy, *T**=0, is an equilibrium state. However, the equilibrium is unstable, leading to bad outcomes, if *F'(0)*>1. Then, whenever *T(0)*>0, no matter how trivially, the dynamic moves *T(t)* toward increasingly bad outcomes. The optimum is locally stable if |*F'(0)*|<1

(ii) Assume *F'(0)*>1 and *F'*>0 for all *T*. In order to prevent policy outcomes to become indefinitely worse once a single error is made, *T(0)*>0, *F'*<1 must hold for large enough *T*. It is plausible to assume that this is true because if special interest distortions became large enough, the incumbents would be positioned so far away from the median voter that it would be easy for challengers to attack them. This would eventually hold true even taking into account the well- known incumbent advantage in U.S. electoral contests. Therefore we assume *F'(T)*<1 for T large enough. Hence if *F'(0)*>1, there will probably be at least one locally stable equilibrium *T**>0.

(iii) Consider an industry seeking a protective tariff *T* against imports. Because tariffs cause deadweight losses, *S(T)*<*C(T)*, the costs outweigh the benefits, so the socially optimal tariff is *T*=0. Then why are there tariffs? Typically, the consumer group is very large with small losses for each household so the noticeability coefficient "*B*" is plausibly zero for the consumer side. For example, no consumer is ever punished for failing to lobby against a sugar tariff that raises prices on all goods containing sweeteners. Free rider problems loom very large for large diffuse groups, so the "perceived effectiveness" coefficient "*A*" is also plausibly zero. Hence, no lobbying against the tariff comes from the consumer side.

Things are quite different on the producer side. Not only is the producer group much smaller but the gains per firm are also much larger, as are the gains to worker from jobs at the producers' factories that might be lost without protection against imports. Hence, we might expect that "peer effects" on the producer side induce contributions from each member; i.e., the "noticeability" coefficient "*b*" is likely to be positive. We might think of "*b*" as a representation of the effect of the peer group parameter *J* in the models discussed in Section 2. Furthermore, the "perceived effectiveness" coefficient "*a*" is plausibly positive because, although, free rider effects will still be present, each factory or union looms large enough relative to the industry that it can be expected to perceive some effect of its individual contributions to the group effort. Thus, we expect a positive level T^* to be a locally stable equilibrium, and we expect $T^*=0$ to be a locally unstable equilibrium that must be constrained by international agreements not to re-raise tariffs, once lowered. We used the tariff as an expository example because of its classic role in the economic analysis of pressure group influence[xv]. This analysis also explains why the only lobbying against protective tariffs is actually conducted by opposing industry associations that happen to use the imported commodity as a raw material or component.

The same analysis can be applied to environmental issues, since the pollution damages are spread out over a diffuse group of victims but the gains from being allowed to pollute are received by a concentrated group. In these cases, our analysis predicts more pollution than socially optimal. However, if the damages from pollution are concentrated on a local community and the benefits to industrial workers, customers, and shareholders of being able to pollute are diffuse, one might even have less pollution than socially optimal. This is the “Not In My Back Yard” (NIMBY) problem. One could approach NIMBY problems by allowing communities to "bid" in a "Willingness To Accept" auction on compensation levels rather than having the plant sited near some politically weak community, as seems often to have been the case. Although it may be more costly to site plants after paying the community enough to induce them willingly to accept the plant, that is good because it reveals the true cost of siting "nuisances" and forces consumers of the outputs of polluting facilities to pay their full social costs.

Leaving NIMBY problems aside, we focus now on cases where the issue is that well-organized, concentrated groups use the political system to extract resources (or impose costs) on poorly organized, and typically diffuse groups. Several remedies are suggested by our rather trivial model:

(a) A heavy burden of proof can be placed on any distortionary policy. This would make $T^{*}=0$ a locally stable equilibrium and induce a threshold at zero that would have to be crossed before the $T(t)$ dynamics could get into the basin of attraction of a locally stable positive steady state T^{*}. Already, for example, tariffs are "bound" by international treaties and cannot be raised except without penalty except in special temporary circumstances. Omnibus legislation such as the National Environmental Policy Act (NEPA) constrains policy actions by the executive branch and subjects it to review. Other environmental legislation, such as FIFRA, prohibits the government from allowing new pesticides on the market without safety and risk-benefit studies.

(b) Since the origin of the problem is the imbalance of power between concentrated and diffuse groups, steps might be taken to make the former more accountable to the latter. For example, corporations could be required to disclose their lobbying activities and positions on public policy issues to their shareholders, a much more diffuse group now including more than 43 million Americans, and gain prior approval for lobbying activities from a committee comprised of independent members of the Board of Directors.

(c) The models focus attention on parameters that determine the relative "social efficacy" of groups in solving their collective social action problems. They suggest that creating a level playing field of "rules" ensuring that all groups will be equally able to create pressure for and against policy changes is key. This implies, for example, that groups on all sides of an issue should be afforded adequate opportunities to be heard during legislative or administrative proceedings. Access to policymaking processes should not be determined by campaign contributions.

(d) A method sometimes used by group entrepreneurs to control free riding in diffuse groups is to offer a joint product consisting of lobbying combined with other desirable goods and services. For example, the AARP lobbies, ostensibly on behalf of seniors, and boosts its membership by offering all sorts of discounted services. The Sierra Club does much the same thing with environmentalists. Of course, competition among such entrepreneurs for members might induce one to "unbundle" the joint product, save money by dropping the expensive lobbying, and offer the services at a cheaper price than rival entrepreneurs. Then the free riding problem would re-emerge[xvi].

This model abstracts from the dynamics of the supply of pressure within each group. One could apply general theory of social interactions as in Durlauf and Young (2001) and Verbrugge's review (2003) to model the dynamics of group supply of political action (i.e. pressure) on both sides of the struggle. The general outcome of this more sophisticated modeling would probably be insights into how the structure of network relationships "social capital" for a group that helps it to overcome its collective action problem. More will be said about this below.

Social Capital

What is the role of "social capital" in allowing a group to solve its collective action problem in mustering more political pressure relative to other groups? Social capital is notoriously difficult to conceptualize or measure precisely but the group that has more of it will be able to muster more political pressure.[xvii] Indeed, inequality across groups in the distribution of social capital is a major problem in democratic political systems and is a major reason why poorly organized public interests are so severely exploited by well-organized special interests. It also helps explains why the political system produces so much deadweight loss that is obvious to economists and other social scientists. Indeed, increased political competition can produce results that reduce social welfare, unlike increased economic competition. (Colander (1984), MBY (1989)).

Consider, for example, state or city governments competing for new investments to generate jobs and growth. In each jurisdiction there are concentrated groups who stand to benefit if a project is attracted and a diffuse public that pays for the tax give-aways and other subsidies, not to mention any other external costs. Therefore, the supply curve in each jurisdiction of incentives for new project exceeds the social welfare optimum supply curve. This alone will create "excess development" in all such jurisdictions. Examples abound of states that "win" a factory paying many times more per new job created than the job pays itself. In such instances, the states could have saved lots of money by hiring new workers themselves. How can this be? Such results can be explained by adding to the political imbalance between special interests and the public in each locale the phenomenon of the "winner's curse" and sheer political myopia.

The "winner's curse" is that the winning bidder usually pays too much. Decisions on how much incentive to offer a potential development are based on economic impact studies that are subject to wide margins of uncertainty. The state that happens to get a high estimate from their economic impact study will tend to bid high and, more often than not, will win, though to the detriment of its economy. It is notoriously hard for people to condition out this effect in preparing optimal bidding strategies, even for professionals like bidders on oil tracts and timber concessions, much less politicians and their staffs.

Add to this the force of political myopia, the tendency of politicians to act to get benefits now and to push the costs onto the next person's watch, plus the imbalance of political pressure within each jurisdiction and one has a sufficient explanation for the widespread destruction of America's environment by uncontrolled development. At the risk of repetition, the remedy is creating institutions that force all cost causers to pay the costs they impose on others.[xviii]

5. Ambiguity Aversion, Peer Effects, and Choice Intensity: A Reason for "Irrational" Inertia

"Ambiguity aversion"[xix] expresses the idea that people react differently when facing situations in which objective probabilities cannot be assigned to possible outcomes. One of the simplest assumptions regarding such ambiguity is that people assume the worst-case outcome within bounds with a width that depends upon their knowledge about the possible outcomes.

This idea can be applied social systems like those analyzed in sections 2 and 3 above. Suppose that only one choice, -1, has been available for a long time. Let now a new choice, +1, appear at date t=0. Assume that the objective systematic part of the utility difference is h>0, implying that the utility generated by choice +1 is objectively better for all members of the community. Nevertheless, the intensity of choice, b, the peer effect C, and the level of ambiguity can interact to deepen a social trap at -1 and make it harder to escape. Here's the idea. Suppose first that there is no ambiguity aversion. Let choice +1 now appear. If there are no peer effects, the difference equation (2.12) above has only one stable state, so it converges from the previous state, -1, to a new stable state that will be nearer to +1, the larger is b. The larger the intensity of choice, the more quickly and closely the community comes to the best choice, +1. Now introduce ambiguity aversion in the following way: let [h-B,h] be an interval that community members believe contains the possibilities for the systematic utility difference right after the availability of the new choice +1 appears. Assum that each agent hedges against possible mis-specification of the systematic part of the gains from moving to +1 by imputing h-B, not h to the net systematic gain. This may describe how the emotional part of the brain reacts when facing a new alternative with which one has no personal experience, before the rational part of the brain has evaluated some accumulated experience. Whatever the explanation, this simple model shows how the intensity of choice b can interact with B to create a social trap.

If h-B<0 and b is huge and positive, the dynamics, (2.12) is stuck near -1 and never escapes even though there are no peer effects. As the intensity of choice decreases, the stable state -1 becomes less resilient as its basin of attraction shrinks. Let B be a function $B(a(t))$ that decreases towards zero as $a(t)$ increases from minus one. This could be a type of demonstration effect that reassures fearful agents once a few agents choosing +1 have been observed getting h out of that choice and not the feared h-B. Notice that a lower b would generate more experiments, so there are more observations of the outcome of choice of +1 available. This reduces B and causes yet more agents to choose +1, creating a positive feedback loop of escape from the bad choice -1 as b is lowered. This process is reminiscent of that described in the Repetto & Allen chapter of fishermen's groups choosing to adopt secure harvesting rights.

The reverse effect occurs when b is increasing and the system starts at the historically given choice -1. If b is infinite and h-$B(a(0)$=-1$)$<0, no one ever chooses +1, so no observations of what actually happens to an agent who made choice +1 is ever available. In contrast, as b decreases, a few agents will happen to choose +1 even though h-$B(a(0)$=-1$)$<0. Then, in the next period B is smaller, which makes it more likely that more choices of +1 appear. This positive feedback loop that was opened up by a reduction in the intensity of choice creates an avenue of escape from a bad social trap. In this context, peer effects just deepen the depth of a social trap because they place an extra cost on departures from the existing consensus at -1. Thus, peer effects cause fewer examples of +1 choice to appear and this keeps people fearful of the new choice, so they continue to assume a worst-case scenario.[xx]

.

This discussion can shed further light on the contest between concentrated special interest groups and diffuse public interest groups. Suppose that there a concentrated subgroup stands to lose if the community moves away from -1, even though the community as a whole stands to gain from a move to +1. How might this concentrated group use its superior ability to muster resources and control free riding within its membership? It could muster and use resources to increase the size of *B* in the minds of the community, increase the intensity of choice *b* in the community, and increase the magnitude of peer effects *C* in the community.

The first strategy could take the form of inducing fear throughout the community by a disinformation (or less politely, a misinformation) campaign. Here is a current example (Table 1) that appeared in the Sunday, October 12, 2003 *Wisconsin State Journal,* entitled "Getting it wrong on the Iraq war".

Table 1: "Getting it wrong on the Iraq war", Many Americans have misperceptions about key facts.

Primary news sources for those who believe:	Since the war ended, the U.S. has found Iraqi weapons of mass destruction	U.S. has found clear evidence that Saddam Hussein was working closely with al-Qaeda terrorist groups
Fox	33%	67%
CBS	23%	56%
NBC	20%	49%
CNN	20%	48%
ABC	19%	45%
P	17%	40%
P/N	11%	16%

Note: P denotes "print media" and P/N denotes PBS/NPR. The WSJ gave the source for this as "PIPA/Knowledge Networks Poll of 3,334 adults, June-September, 2003, 1.7 percentage points error margin."

Since the answer should have been approximately zero percent for the first belief and probably close to zero percent for the second belief, this table suggests a clustering at -1, the “wrong” choice, induced by history dependence, peer effects, induced high strength of belief (high choice intensity, "b"), and induced fear of worst-case scenarios (perhaps induced by the 9-11 horror) amongst different peer groups who adhere to the media sources listed above. Since each group's dominant media source probably induces correlations that help stick the audience on the wrong belief –1 and induce bias in the perceived intrinsic merit of the beliefs, the observed behavior may be consistent with a type 3 mechanism as well as a type 2 mechanism. Indeed, if the Fox network dramatically switched its position, we could even test which system applied by observing whether its audience dramatically shifted its belief or whether the audience's beliefs remained sticky.

Clearly if a special interest group, which could include a faction within the government, can use its resources to induce different media to propagate desired beliefs throughout the community, increase the intensity with which those beliefs are held and create or strengthen peer effects that punish dissenters, it could effectively freeze public opinion in a bad choice and create a very resilient attractor of the social dynamics at the stable state -1.

6. Application: Adoption of ITQ's (Robert Repetto and Richard Allen)

Consider a group of fishermen who have operated under a fisheries management system that is plagued with rent dissipation problems. Call this institutional situation -1. Assume an alternative management approach +1 appears that economists are sure will benefit the fishermen as a group. Of course, some of the fishermen may lose but suppose that the gainers will gain more than the losers will lose and so could fully compensate the losers and still have a surplus. But, since none of the fishermen have operated under +1, suppose each of them is ambiguity averse and believe their own gain could take any value in the interval $[h\text{-}B(0),h]$. Thus, even though $h>0$, the worst-case outcome at date 0 is $h\text{-}B(0)<0$. Thus, Section 5's results predict that the fishing community will stick at -1 and will oppose any move towards +1. If the intensity of choice is large and there are peer effects, few will try +1 even if they are free to do so. If more than a threshold level have to choose +1 before it is allowed, this creates an additional force to stick the system at -1. Scientists could attempt to shift the debate by publicizing the experience of New Zealand fisheries (Hartley (1997)) or the natural experiment between Canadian and U.S. scallop fisheries (Repetto (2001)) but this is not nearly as convincing as the personal experience of a neighbor.

A main issue in any rights-based system is how to allocate the tradable rights initially. Heterogeneity of interests within the fishing community is one major source of difficulty in deciding upon an initial allocation. If there is a lot of heterogeneity that is not common knowledge, room is left for posturing by individual fishermen attempting to gain a larger share of the valuable rights. An aggressively selfish one could hold up action in an attempt to capture rents causing the negotiations to break down. However, if fishermen's circumstances and fishing histories are common knowledge, it will be more difficult for any one of them to claim special treatment in the initial rights allocation. Bewley (1986) points out that uncertainties about the outcomes of such bargaining games could cause the very ambiguity we discussed in Section 5 in people's minds about how institution +1 will actually operate in reality and what benefits they would experience.

7. Summary and Conclusions

This paper shows how simple discrete choice models of group dynamic choice can shed light on the ways group pressure on policy makers induces moves for or against the status quo relative to one or more alternatives. It has shown how the interaction of dynamics within groups with the forces of conformity and/or complementarity, as well as the effect on the group effort of controls over free riding by group members, can produce policy macro-punctuations, e.g. abrupt changes, which seem inexplicable in terms of observable fundamentals. The analysis has shown how policies can remain static for long periods in the face of changing underlying fundamentals and how, in contrast, slow or modest changes in those fundamentals can occasionally lead to abrupt and discontinuous policy shifts.

We hope that this kind of analysis can help in enhancing understanding of abrupt changes in the policy domain and the ability to use observable facts to locate "lever points" where small efforts can be applied to escape policy "lock-in" bad social states, so that endogenous social dynamics can move the system to a better social state.

References

Amaro de Matos, J., Perez, J., (1991), "Fluctuations in the Curie-Weiss version of the random field Ising model, JOURNAL OF STATISTICAL PHYSICS, 62: 587-608.

Anderson, S., de Palma, A., Thisse, J., (1992), DISCRETE CHOICE THEORY OF PRODUCT DIFFERENTIATION, Cambridge: MIT Press.

Arthur, W., Durlauf, S., Lane, D., (1997), THE ECONOMY AS AN EVOLVING COMPLEX SYSTEM II, Reading, MA.: Addison-Wesley.

Axelrod, R., (1984), THE EVOLUTION OF COOPERATION, New York: Basic Books.

Axelrod, R., (1997), THE COMPLEXITY OF COOPERATION: AGENT-BASED MODELS OF COMPETITION AND COLLABORATION, Princeton: Princeton University Press.

Baumgartner, F., (2003), "Punctuated equilibrium models of policy change and stability," Department of Political Science, The Pennsylvania State University.

Bayer, P., Timmins, C., (2001), "Identifying social interactions in endogenous sorting models," Department of Economics, Yale University.

Bewley, T., (1986), "Knightian decision theory: Part I," Cowles Foundation Discussion Paper, CFDP 807, Department of Economics, Yale University.

Bewley, T., (1987), "Knightian Decision Theory, Part II, Intertemporal problems," Cowles Foundation Discussion Paper, CFDP 835, Department of Economics, Yale University.

Brock, W., (1993), "Pathways to randomness in the economy: Emergent nonlinearity and chaos in economics and finance," ESTUDIOS ECONOMICOS, 8, 3-55.

Brock, W., (2000), "Some mathematical tools for analyzing complex nonlinear systems," SSRI Working Paper, http://www.ssc.wisc.edu/~wbrock.

Brock, W., (2001), "Economics for Ecologists: A Reader's Guide," SSRI Working Paper, http://www.ssc.wisc.edu/~wbrock. Also see the White Papers on Ann Kinzig's website, http://lsweb/la.asu.edu/akinzig/white_papers.htm.

Brock, W., Durlauf, S., (1999), "A formal model of theory choice in science," ECONOMIC THEORY, 14: 113-130.

Brock, W., Durlauf, S., (2001a), "Discrete choice with social interactions," REVIEW OF ECONOMIC STUDIES 68: 235-260.

Brock, W., Durlauf, S., (2001b), "Interactions-based models," in J. Heckman and E. Leamer (eds.), HANDBOOK OF ECONOMETRICS V, Amsterdam: North-Holland.

Brock, W., Durlauf, S., (2002), A multinomial choice model of neighborhood effects," AMERICAN ECONOMIC REVIEW 92(2): 298-303.

Brock, W., Durlauf, S., (2003), "Multinomial choice with social interactions," NBER W.P. 288, http://www.nber.org.

Brock, W., Durlauf, S., West, K., (2003), "Policy evaluation in uncertain economic environments," BROOKINGS PAPERS IN ECONOMIC ACTIVITY, Volume 1, 235-322.

Brock, W., LeBaron, B., (1996), "A dynamic structural model for stock return volatility and trading volume, "REVIEW OF ECONOMICS AND STATISTICS, 78(1): 94-110.

Brock, W., Hommes, C., (1997), "A rational route to randomness," ECONOMETRICA, 65(5), 1059-1095.

Brock, W., and Taylor, S., (2003a), "The Kindergarten Rule of sustainable growth," SSRI Working Paper, http://www.ssc.wisc.edu/~wbrock.

Brock, W., and Taylor, S., (2003b), "Economic growth and the environment: Matching the stylized facts," SSRI Working Paper, http://www.ssc.wisc.edu/~wbrock.

Brown, C., (1995), SERPENTS IN THE SAND, Ann Arbor: University of Michigan Press.

Carpenter, S., Brock, W., (2004), "Spatial complexity, resilience, and policy diversity: Fishing on lake-rich landscapes," ECOLOGY AND SOCIETY, http://www.ecologyandsociety.org/vol9/iss1/.

Colander, D., (ed.), (1984), NEOCLASSICAL POLITICAL ECONOMY: THE ANALYSIS OF RENT-SEEKING AND DUP ACTIVITIES, Cambridge, MA.: Ballinger Publishing Company.

Colander, D. (ed.), (2000), THE COMPLEXITY VISION AND THE TEACHING OF ECONOMICS, Cheltenham: Edward Elgar.

De Fontnouvelle, P., (2000), "Information dynamics in financial markets," MACROECONOMIC DYNAMICS, Vol. 4, No. 2, June.

Durlauf, S., (2002), "On the empirics of social capital," THE ECONOMIC JOURNAL, Vol. 112, No. 483, November, F450-F479.

Durlauf, S., Young, P., (eds.), (2001), SOCIAL DYNAMICS, Cambridge: MIT Press.

Durlauf, S., Fafchamps, M., "Empirical studies of social capital: a critical survey," SSRI Working Paper, 2003-12.

Ellis, R., (1985), ENTROPY, LARGE DEVIATIONS, AND STATISTICAL MECHANICS, New York: Springer-Verlag.

Evans, D., ed., (1983), BREAKING UP BELL: ESSAYS ON INDUSTRIAL ORGANIZATION AND REGULATION, Amsterdam: North Holland.

Gunderson, L., Holling, C., (eds.), (2002), PANARCHY: UNDERSTANDING TRANSFORMATION IN HUMAN AND NATURAL SYSTEMS, Washington, D.C.: Island Press.

Hansen, L., Sargent, T., (2003), ROBUST CONTROL AND MODEL UNCERTAINTY IN MACROECONOMICS, Department of Economics, The University of Chicago and New York University.

Hartley, P., (1997), CONSERVATION STRATEGIES FOR NEW ZEALAND, New Zealand Business Roundtable, The Terrace, Wellington, New Zealand.

Heal, G., Kunreuther, H., (2003), "You only die once: Managing discrete interdependent risks," www.gsb.columbia.edu/faculty/gheal.

Jones, B., Baumgartner, F., True, J., (2002), "Policy macropunctuations: How the U.S. budget evolved," Department of Political Science, University of Washington, Pennsylvania State University, and Lamar University.

Kuznetsov, Y., (1995), ELEMENTS OF APPLIED BIFURCATION THEORY, Berlin: Springer-Verlag.

Magee, S., Brock, W., Young, L., (1989), BLACK HOLE TARIFFS AND ENDOGENOUS POLICY THEORY: POLITICAL ECONOMY IN GENERAL EQUILIBRIUM, Cambridge: Cambridge University Press.

Milgrom, P., Roberts, J., (1992), ECONOMICS, ORGANIZATION AND MANAGEMENT, Englewood Cliffs: Prentice-Hall.

Nordhaus, W., (1992), "Lethal model 2: the limits to growth revisited," BROOKINGS PAPERS ON ECONOMIC ACTIVITY (2): 1-59.

Olson, M., (1965), THE LOGIC OF COLLECTIVE ACTION: PUBLIC GOODS AND THE THEORY OF GROUPS: Cambridge: Harvard University Press.

Ostrom, E., (1990), GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION, Cambridge: Harvard University Press.

Ostrom, E., Gardner, R., Walker, J., (1994), RULES, GAMES, AND COMMON-POOL RESOURCES, Ann Arbor: University of Michigan Press.

Repetto, R., (2001), A natural experiment in fisheries management, MARINE POLICY 25: 251-264.

Rosser, J., (1991), FROM CATASTROPHE TO CHAOS: A GENERAL THEORY OF ECONOMIC DISCONTINUITIES, Dordrecht: Kluwer Academic Publishers.

Scheffer, M., Westley, F., Brock, W., (2003), "Slow response of societies to new problems: causes and costs," ECOSYSTEMS 6: 493-502.

Scheffer, M., Westley, F., Brock, W., (2000), "Socioeconomic mechanisms preventing optimum use of ecosystem services: an interdisciplinary theoretical analysis," ECOSYSTEMS 3: 451-471.

Verbrugge, R., (2003), "Interactive-agent economics: An elucidative framework and survey of results," MACRODECONOMIC DYNAMICS, Volume 7, No. 3, June, pp. 424-472.

---

[i] I thank Robert Repetto for essential help in editing and writing this paper. I thank Giacomo Rondina for excellent help with formatting and preparation of graphs. None of the above are responsible for errors.

[ii] Discussions that are quite accessible but still precise enough to clarify the underlying science include Arthur, Durlauf, and Lane (1997), Durlauf and Young (2001), Colander (2000), and Gunderson and Holling (2002).

[iii] See Durlauf and Young (2001) for an extensive discussion of this very difficult problem.

[iv] Although the modeling relies on some mathematics in Brock and Durlauf (2001a,b) and Scheffer et al. (2000, 2003), we shall attempt to explain everything here in plain English. Readers that are not satisfied with the imprecision of English are encouraged to consult these references. The two articles by Scheffer et al. explain these ideas with minimal mathematics. I will also minimize the use of mathematics but a modest amount is necessary.

[v] See the review of Durlauf and Young (2001) with special attention to the work of Charles Manski on identification of peer effects and Glaeser and Scheinkman's work on modelling social interactions.

[vi] We point out for readers who want to follow up on mathematical details of this kind of modeling, that many formulations, including the one used above, lead to standard cross sectional Laws of Large Numbers, Central Limit Theorems, and Least Absolute Deviations Theorems (Brock (1993), Ellis (1985)) even though there are alternative stable states, as long as agents are assumed to form certain predictions of the group average.

[vii] This is explained more fully in Brock and Durlauf (2001a). Readers who wish to see the rather difficult mathematics that justifies this result are urged to look at Brock (1993), BD(1999), and BD(2001a,b).

[viii] There is a close relationship between the problem of predicting the impending rapid shifts in social system dynamics that are the concern of this paper and the problem of predicting regime shifts in ecology (Gunderson and Holling (2002)). Ecological analysis stresses the role of drivers (our h's) which are typically slow moving as well as nonlinearities caused by positive feedback loops in producing rapid shifts.

[ix] For mathematically inclined readers who wish to see the mathematical foundations of this result, we note that Ellis (1985) does a nice job of explaining how increasing "b" and/or J from $bJ<1$ to $bJ>1$ causes the "correlation lengths" amongst agents to "lengthen" in such a way that an infinite series which measures the "system wide" strength of these correlations diverges. This divergence behavior enables the system to "escape the dead hand of history" and "leap" from a negative equilibrium to a positive equilibrium as "h" changes from negative to positive, no matter how small this change is.

[x] Restriction of attention to binary cases as we have done to date is very limiting. However recent work by Bayer and Timmins (2001) and Brock and Durlauf (2002, 2003) has considered discrete choice dynamics with more than 2 choices. Brock and Durlauf (2002), (2003) show that the number of alternative stable states multiplies rapidly with the number of distinct choices. They also show how recent work on "Curie-Weiss-Potts" models in statistical mechanics can produce results analogous to Result 3.1. Such multinomial models are very interesting because the number of equilibria across which the system can jump becomes large as peer effects appear and choices proliferate, raising the potential for phase transitions.

[xi] This is the classic Mancur Olson (Olson (1965)) problem treated by his classic book (Olson (1965)). Olson's work, together with other ideas from social and political science, were used by Magee, Brock, and Young (1989), (hereafter MBY(1989)) in building a general theory of endogenous policy change.

[xii] It can also be modeled as a repeated game (Ostrom, Gardner, and Walker (1994), hereafter OGW (1994)). Alternatively, MBY (1989) model this problem as a Nash non-cooperative game in the spirit of Olson (1965) and capture elements of Axelrod and OGW (1994) by using two parameters, "noticeability" and "perceived effectiveness." Noticeability measures the extent to which free riders can be punished later on by some group sanction. (Axelrod (1997)) Perceived effectiveness measures an agent's belief about the effectiveness of his contribution to the group's goal.

[xiii] Here we adapt MBY's Mathematical Appendix (1989).

[xiv] More elaborate functional forms that include the opposition's contributions are given in MBY (1989). MBY report empirical work using a "power index" (which is a product of the total sum of stakes and a concentration index of those stakes) to measure the effective supply of pressure by each group.

[xv] Indeed, in late 2003, at the time of this writing, steel tariffs are a top news story. In this particular case the users were concentrated and had a power index roughly equivalent to that of the producers. The Bush administration had first

catered to the producers and imposed steel tariffs. The users (including auto producers) were roughly equally concentrated and mustered strong pressure to remove the tariffs. A final threat from the rest to the world "tipped" the Bush administration into removing the tariffs. This very brief discussion illustrates a key point we wish to make in this paper. A potentially useful approach to organizing action to remove bad policies would be to locate situations where the "power indices" of groups for and against a current bad policy are roughly equal. Then allocate resources towards "tipping" the system away from bad policies in these particular situations. The Bush administration steel tariffs are a good illustration of this strategy. Standard economic benefit cost analysis like that used by MBY suggests that tariffs cause more damage than benefit. Our suggested policy improvement algorithm focuses attention of reformers upon situations where the pressure groups are roughly "balanced" as was the case for the Bush administration steel tariffs. This example suggests a potential blueprint for environmental action: Use a data base to locate bad environmental policies where well organized and powerful pressure groups are roughly balanced for and against. Allocate political action resources to "tip" each "balanced" bad policy towards a good policy.

[xvi] The model also can be used to prompt discussions of campaign finance reform in the U.S. political system and why it is so difficult. If money is taken out of politics, something else will replace it that might be worse, such as incumbent advantage that can not be matched by challengers. Of course, after money is banned, the state could fund challenger campaigns at an excess ratio $R>1$ to incumbent campaigns where R is set to "equalize" challenger advantage to incumbent advantage. But what about such groups as the elderly and labor whose contributions are measured in terms of human effort rather than money. Banning private contributions of money may end up turning the political system over to groups who contribute human effort rather than money. The model helps keep the mind focused on the heart of the problem: Creation of a level playing field in the sense laid out above.

[xvii] See Durlauf (2002) and Durlauf and Fafchamps (2003) for detailed reviews and discussion of the literature on social capital.

[xviii] See my White Paper (Brock (2001)) for a discussion (in English, not mathematics) of this case as well as many issues related to the topics covered in this paper.

[xix] There has been much interest recently in modeling ambiguity aversion, which is sometimes called Knightian Uncertainty. We borrow here from models developed by Bewley (1986), (1987), Hansen and Sargent (2003), Brock, Durlauf, and West (2003), Brock and Durlauf (2003).

[xx] It is interesting to compare behaviors under Results of type 2 and type 3. In the type 3 case, nontrivial stochastic correlations are induced via peer effects in addition to the standard deterministic dependencies across choices captured in type 2 Results. Hence, when $h-B(a(t))$ passes through zero, the type 3 system immediately leaps to a point $a(t+1)$ close to +1 and locks onto a state close to +1 as long as h remains positive